

Table 4-20. Frequencies of americium-241 detection in sampled media.

Media	Detection Rate (%)	Range of Detected Concentrations	Total Number of Detections Higher than the Risk-Based Concentration ^a	Wells with Detections Higher than the Risk-Based Concentration ^a
Waste zone	Boreholes: 56 Measurements: 22	0.035 to 30.4 pCi/g	0	None
Surface soil	72.4	0.01 to 1.6 pCi/g	0	None
Surface runoff	8.6	0.067 to 3.8 pCi/L	0	None
Vadose zone (0 to 35 ft):				
Cores	16.7	0.012 to 9.6 pCi/g	0	None
Soil moisture	4.8	0.30 to 9	1	PA01
Vadose zone (35 to 140 ft):				
Cores				
Soil moisture	18.0	0.006 to 0.908 pCi/g	0	None
	7.5	0.8 to 2.4 pCi/L	0	None
Vadose zone (140 to 250 ft):				
Cores				
Soil moisture	2.8	0.016 to 0.033 pCi/g	0	None
	3.5	0.041 to 0.14 pCi/L	0	None
Vadose zone (>250 ft):				
Cores	0	Not analyzed	0	None
Aquifer-Idaho National Engineering and Environmental Laboratory	1.9	0.011 to 1.97 pCi/L	0	None
Aquifer-U.S. Geological Survey	4.7	0.01 to 5 pCi/L	1	USGS-89

a. The calculated 1E-05 risk-based concentration (RBC) for soil is 36.6 pCi/g. For lysimeter, perched water, and aquifer samples, the calculated 1E-05 aquifer RBC is 4.6 pCi/L, which does not apply to perched water and lysimeter samples but is presented as a basis for comparison.

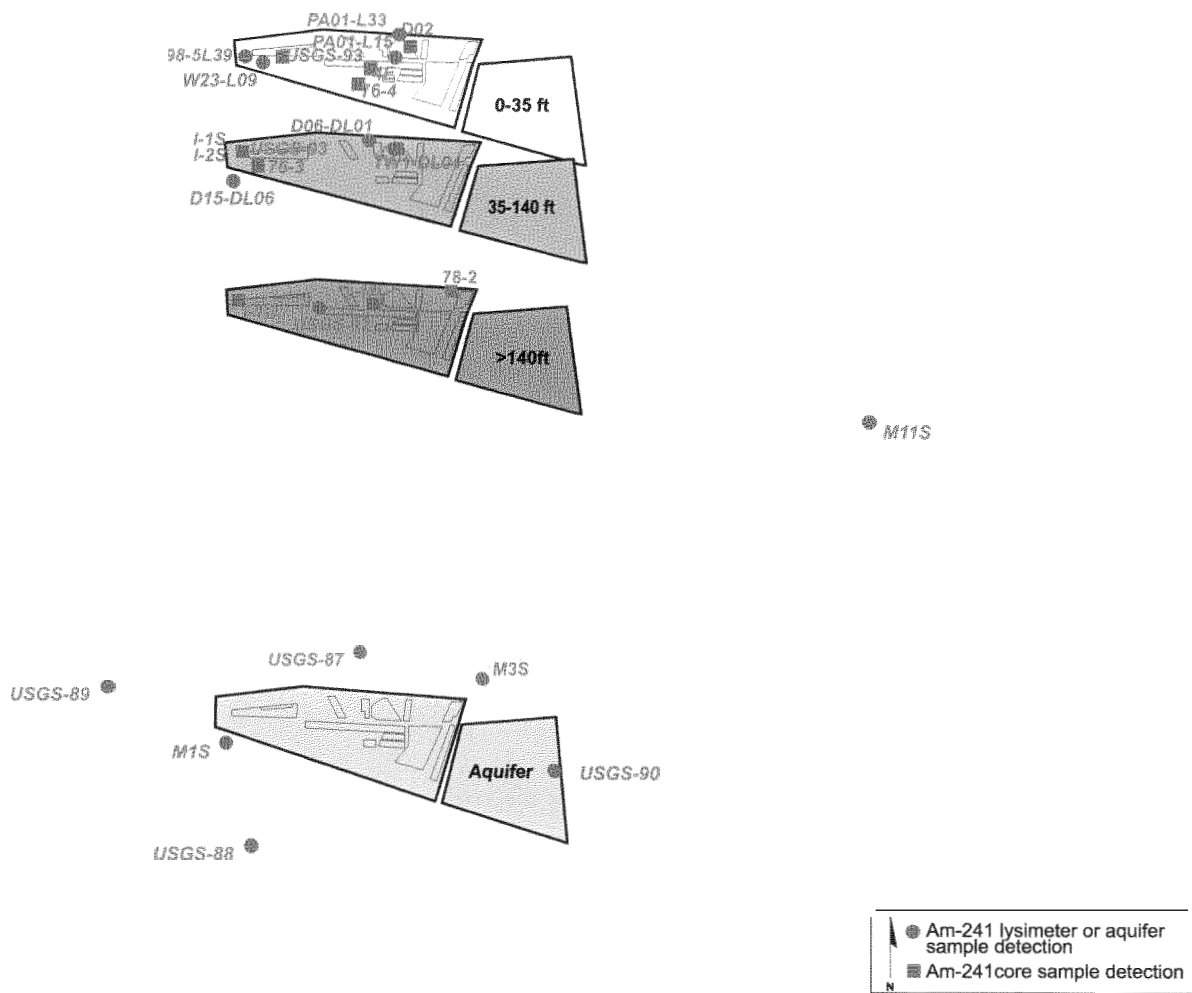


Figure 4-17. Locations of americium-241 detections in vadose zone core, lysimeters, and the aquifer.

4.6.3 Americium-243

Americium-243 is an anthropic, transuranic radioisotope that is produced from nuclear reactor operations and weapons manufacturing and testing. It decays by the emission of alpha particles, has a 7,370-year half-life. Americium-243 was identified as a COPC in the IRA, primarily from the external exposure pathway (Becker et al. 1998), and because it is the long-lived parent of another COPC, Pu-239. It was explicitly modeled to assess the affects of progeny ingrowth on fate and transport and on cumulative risk from Pu-239. Americium-bearing waste in the SDA are summarized below.

Americium-243 has not been included on the ER Program radionuclide target list provided to the analytical laboratories subcontracted to the INEEL. It is not essential to routinely sample and analyze for Am-243 because (a) the presence of Am-243 can be inferred from detection of its gamma-emitting progeny (Np-239) above the detection limit (about 10 pCi/L) by routine gamma spectrometric analysis, (b) to analyze specifically for Am-243, a nonroutine radiometric tracer would be required, and the sample would have to be prepared and analyzed separately from customary americium analysis, (c) concentrations would likely be below the method detection limit, and (d) Am-243 was not retained for further risk analysis in the IRA (Becker et al. 1998).

4.6.3.1 WasteZone. Approximately 1.34E+02 Ci of Am-243 were disposed of in the SDA. The waste streams containing the majority of Am-243 activity are identified in Table 4-21. Americium-243 decays to produce Pu-239, U-235, Pa-231, and Ac-227 (see Section 4.1.2). However, because of the small initial inventory, the relative contribution to the total inventory of the daughter products is small.

Table 4-21. Waste streams containing americium-243.

Waste Stream Code or Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
Idaho National Engineering and Environmental Laboratory (INEEL)	INEEL reactor operations waste	1.34E+02	99.6
Miscellaneous	Miscellaneous minor streams	-0	0.4
Total Disposals		1.34E+02	100

4.6.3.2 Summary of Americium-243. No analytical data are available for Am-243.

4.6.4 Carbon-14

Carbon-14 is a radioisotope generated by nuclear operations as an activation product. It decays by the emission of beta particles and has a 5,715-year half-life. It also occurs naturally with low abundance in the environment. Carbon-14 was identified in the IRA as a COPC, primarily for the groundwater ingestion exposure pathway (Becker et al. 1998).

Carbon-14-bearing waste in the SDA and the available C-14 monitoring data for all media are summarized below. Monitoring for C-14 began after the PSRA (Bums et al. 1994; Loehr et al. 1994) and the LLW Radiological Performance Assessment (Maheras et al. 1994) identified C-14 as a possible contributor to unacceptable risk or dose. The sampling data in this section are evaluated against the comparison concentrations in Table 4-22.

Table 4-22. Comparison concentrations for carbon-14 in groundwater and soil.

Surface Soil Background Concentration (pCi/g)	Risk-Based Soil Concentration ^a (pCi/g)	Aquifer Background Concentration	Maximum Contaminant Level (pCi/L)	Risk-Based Aquifer Concentration ^a (pCi/L)
Not established	2,845	Not established	2,000	307

a. Calculated risk-based concentration, equivalent to an increased cancer risk of 1E-05.

4.6.4.7 Waste Zone. Approximately 500 Ci of C-14 were disposed of in the SDA. Waste streams containing the majority of C-14 activity are identified in Table 4-23. Gamma spectral logging in the waste zone provides no information about C-14.

Table 4-23. Waste streams containing C-14.

Waste Stream Code or Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
Test Reactor Area (TRA)	Activation products.	2.08E+02	41.7
NRF-616-3H, 4H, 8H	Core structural pieces.	1.07E+02	21.3
TRA	Beryllium waste.	9.26E+01	18.5
CPP-603-1H	Fuel end pieces.	4.58E+01	9.2
Argonne National Laboratory-West	Subassembly hardware.	1.66E+01	3.3
Miscellaneous	Miscellaneous minor streams.	1.45E+01	2.9
TRA-603-1H	TRA resins.	7.81E+00	1.6
ANL-785-1	Subassembly low-level waste from the Hot Fuel Examination Facility experiments.	7.51E+00	1.5
Total Disposals		5.00E+02	100

4.6.4.2 Surface No data are available because C-14 has not been a target analyte for surface sampling.

4.6.4.3 Vadose Zone. The distributions of C-14 in vadose zone core, soil moisture, and perched water in the various depth intervals are discussed below.

4.6.4.3.1 Vadose Zone Core Samples — A total of 52 core samples were analyzed for C-14 between 1994 and 2000 and no positive detections. Previous core sampling investigations from 1971 to 1993 did not analyze for C-14 because it was not identified as a radionuclide of concern until 1994 (Burns et al. 1994; Loehr et al. 1994; Maheras et al. 1994). The distribution of samples over the depth intervals is shown in Table 4-24.

Table 4-24. Distribution of C-14 in vadose zone core samples in the various depth intervals.

Depth Interval (ft)	Number of Detections/ Number of Samples (%)	Range (pCi/g)	Cores with Detections
0 to 35	0/11 (0)	Not detected	None
35 to 140	0/25 (0)	Not detected	None
140 to 250	0/16 (0)	Not detected	None
Greater than 250	0/0 (0)	Not detected	None

4.6.4.3.2 Lysimeter Samples at Depths from 0 to 35 ff—A total of 59 shallow lysimeter samples were analyzed for C-14 between 1997 and September 2000, with seven positive detections as shown in Table 4-25. Five of the seven positive detections were from one lysimeter (i.e., PA02-L16). The occurrence of C-14 detections in the shallow lysimeter samples is shown in Figure 4-18.

Only the August 1997 C-14 results for Lysimeter PA02-L16 was a confirmed positive detection by reanalysis of the original sample. The other samples that contained detectable C-14 were of insufficient volume to perform the confirmation analyses. Concentrations in Lysimeter PA02-L16 appear to be increasing over time, though the concentrations are still one order of magnitude below the aquifer RBC of 307 pCi/L used for comparison. The most recent sample collected from Lysimeter PA02-L16 did not contain detectable concentrations of C-14. In fact, none of the recent lysimeter samples have shown positive detections of C-14.

Table 4-25. Positive detections of carbon-14 in shallow lysimeters.

Lysimeter	Depth (ft)	Concentration \pm 1 σ (pCi/L)	Confirmation Flag ^a	Date
PA02-L16	8.7	16 \pm 3	A	April 1997
		18 \pm 4	D	August 1997
		19 \pm 4	D	August 1997
		21.8 \pm 1.9	A	April 1998
		26 \pm 5	A	May 1999
W06-L27	11.8	11 \pm 3	A	April 1997
98-4L38 (SDA-08)	17	24 \pm 5	A	May 1999

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

D = Detection confirmed by reanalysis.

Note: Highlighted values are the original and confirmation analyses. Positive detection was confirmed.

4.6.4.3.3 Lysimeter Samples at Depths of 35 to 740 ff—A total of eight lysimeter samples from the three wells were analyzed for C-14 between 1997, when C-14 monitoring began, and November 1998, with no positive detections. Only samples from Lysimeters D06-DL02, TW1-DL04, and D15-DL06 were analyzed for C-14; the other lysimeter samples did not yield sufficient water volume during sampling to perform the C-14 analysis.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01- L15	PA02- L16	PA03- L33	W06-L27	W08-L13	W08-L14	W23-L08	W25-L28
1997	1											
	2					16		11				
	3					19						
	4											
1998	1											
	2					21.8						
	3											
	4											
1999	1											
	2		24			26						
	3											
	4											
2000	1											
	2											
	3											
	4											
2001	1											
	2											
	3											
	4											
Key		Analysis was performed for C-14 , but none was detected.										
		C-14 was detected (pCi/L).										
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.										

Figure 4-18. Occurrence of carbon-14 in shallow lysimeters (in pink).

4.6.4.3.4 Perched Water Samples at Depths Greater than 140 ft—A total of 10 water samples and nine filtered sediment samples from the perched water wells were analyzed for C-14 between 1997 and November 1999. There were five positive detections of C-14 in the water samples and four positive detections in the filtered sediments. None of the perched water samples exceed the aquifer RBC of 307 pCi/L used for comparison. Results for filtered sediments from the samples were all less than 2,845 pCi/g, the 1E-05 RBC for surface soil (see Table 4-26). The RBCs do not apply to lysimeters and are provided here only as a basis of comparison.

Well USGS-92 filtrate and filtered fractions yielded repeated detections of C-14, though three more recent sampling events have not indicated C-14 presence in that well. The USGS does not analyze the perched water from Well USGS-92 for C-14.

No data are available for the deep lysimeter samples because the volumes of water collected were insufficient to perform the C-14 analysis.

The vadose zone soil moisture sample results are well below the aquifer RBC for C-14, and the filtered sediments are below the 1E-05 RBC for surface soil. The aquifer and soil RBC are not applicable to lysimeter results and are used only for comparison.

Table 4-26. Positive detections of carbon-14 in perched water.

Well	Depth (ft)	Concentration \pm (1 σ) (pCi/L) Water	Confirmation Flag ^a	Concentration \pm (1 σ) (pCi/g) Filtered Sediments	Confirmation Flag ^a	Date
8802D	220	20 \pm 4	A	Analyzed for, but not detected (ND)	None	February 1998
USGS-92	214	12 \pm 3	A	0.63 \pm 0.09	A	April 1997
		13 \pm 2	B	ND	None	August 1997
		mi 4	D	ND	None	February 1998
		14 \pm 4	D	0.51 \pm 0.12	B	February 1998
		ND	None	0.54 \pm 0.15	A	April 1998
		ND	None	3.2 \pm 0.5	A	March 1999

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

B = Reanalysis performed, no confirmation.

D = Detection confirmed by reanalysis.

Note: Highlighted values are the original and confirmation analyses. Positive detection was confirmed.

4.6.4.4 Aquifer. Aquifer monitoring for C-14 began in 1994. A total of 239 samples were analyzed for C-14 between 1994 and April 2001, returning 19 positive detections as summarized in Table 4-27. The distribution of detected concentrations of C-14 over the entire span of C-14 aquifer monitoring is shown in Figure 4-19.

Aquifer Wells M12S and M13S, with three or more detections, are located approximately 1 to 2 miles upgradient from the SDA. Carbon-14 may be migrating from the SDA in a vapor phase or originate from INTEC or TRA.

The concentrations of C-14 are one to two orders of magnitude below the 1E-05 aquifer RBC for C-14, which is 307 pCi/L.

Data collected in September 1996 suggested seven other positive C-14 results that are not included in this analysis because of unacceptable data quality. These seven results were reevaluated and classified as either false positive or estimated results because C-14 also was detected in the corresponding field blank at a concentration equivalent to those in the sample results. The September 1996 data were revalidated and a revised limitations and validations report was issued^a.

The USGS does not analyze for C-14 in the eight wells that they manage, control, and routinely sample.

a. John Schaffer, Bechtel BWXT Idaho, LLC, Letter to Kathleen Hain, U.S. Department of Energy Idaho Operations Office, January 31, 2002, CCN 29543, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

Table 4-27. Positive detections of carbon-14 in aquifer wells.

Aquifer Well	Concentration $\pm 1\sigma$ (pCi/L)	Confirmation Flag ^a	Date
M1S	4.9 \pm 0.6	A	January 1999
	2.8 \pm 0.7	A	July 2000
M3S	3.3 \pm 0.7	A	July 2000
M4D	5.7 \pm 1.7	B	June 1994
	28 \pm 5	B	January 1995
M6S	5.3 \pm 0.5	A	October 1999
M7S	1.8 \pm 0.5	B	October 1999
	2.2 \pm 0.7	D	July 2000
	2.2 \pm 0.7	D	July 2000
M11S	2.8 \pm 0.8	B	April 2001
M12S	3.0 \pm 0.9	A	July 1998
	4.4 \pm 0.5	A	January 1999
	2.1 \pm 0.7	A	July 2000
	2.9 \pm 0.8	A	April 2001
M13S	6.7 \pm 0.9	A	July 1998
	3.2 \pm 0.7	A	July 2000
	3.3 \pm 0.8	A	April 2001
M14S	10.9 \pm 0.7	A	July 1999
	4.0 \pm 0.9	A	September 2000

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

B = Reanalysis performed, no confirmation.

D = Detection confirmed by reanalysis.

Note: Highlighted values are the original and confirmation analyses. Positive detection was confirmed.

4.6.4.5 Summary of Carbon-74. Carbon-14 was identified as a COPC for the groundwater ingestion exposure pathway (Becker et al. 1998). Carbon-14 is not included in routine surface monitoring, but has been monitored in the vadose zone since 1997 and in the aquifer since 1994. Carbon-14 has been detected in lysimeter, perched water, and aquifer well samples, but not in any of the vadose zone core samples (see Table 4-28). The distribution of the C-14 detections in the various depth intervals at the SDA is shown in Figure 4-20.

Detected concentrations of C-14 are sporadic and are two to three orders of magnitude below the MCL of 2,000 pCi/L. Five of the seven shallow lysimeter detections were from Well PA01 near Pad A.

It appears that C-14 is present in the aquifer. The most frequent aquifer detections occur in aquifer Wells M12S and M13S, which are hydrologically upgradient from the SDA. The upgradient detections of C-14 are not yet understood, but may be caused by vapor transport from the SDA or from unidentified upgradient sources.

Table 4-28. Carbon-14 detection rates for the sampled media.

Media	Detection Rate (%)	Range of Detected Concentrations	Total Number of Detections Greater than Risk-Based Concentration ^a	Wells with Detections Greater than Risk-Based Concentration
Vadose zone (0 to 35 ft):				
Cores	0	Not applicable (NA)	0	None
Soil moisture	11.9	11 to 26 pCi/L	0	None
Vadose zone (35 to 140 ft):				
Cores	0	NA	0	None
Soil moisture	0	NA	0	None
Vadose zone (>140 ft):				
Cores	0	NA	0	None
Soil moisture	50	12 to 20 pCi/L	0	None
Aquifer	7.9	1.8 to 28 pCi/L	0	None

a. For core samples, the 1E-05 risk-based concentration (RBC) is 2,845 pCi/g. For soil moisture and aquifer samples, the RBC applied was 307 pCi/L. The RBC does not apply to soil moisture and perched water samples, but is used here as a basis of comparison.

Figure 4-19. Occurrence of carbon-14 detections in the aquifer monitoring wells, 1994 through April 2001.

Year	Quarter	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	A11A31	OW-2
1994	1															
	2	5.7														
	3															
	4															
1995	1															
	2															
	3															
	4															
1996	1															
	2															
	3															
	4															
1997	1															
	2															
	3															
	4															
1998	1															
	2															
	3															
	4															
1999	1	4.9														
	2															
	3															
	4															
2000	1															
	2															
	3	2.8	3.3			2.2			2.1	3.2	4.0					
	4															
2001	1															
	2															
	3															
	4															

Key

Analysis was conducted for C-14, but none was detected.

C-14 was detected (pCi/L).

If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.

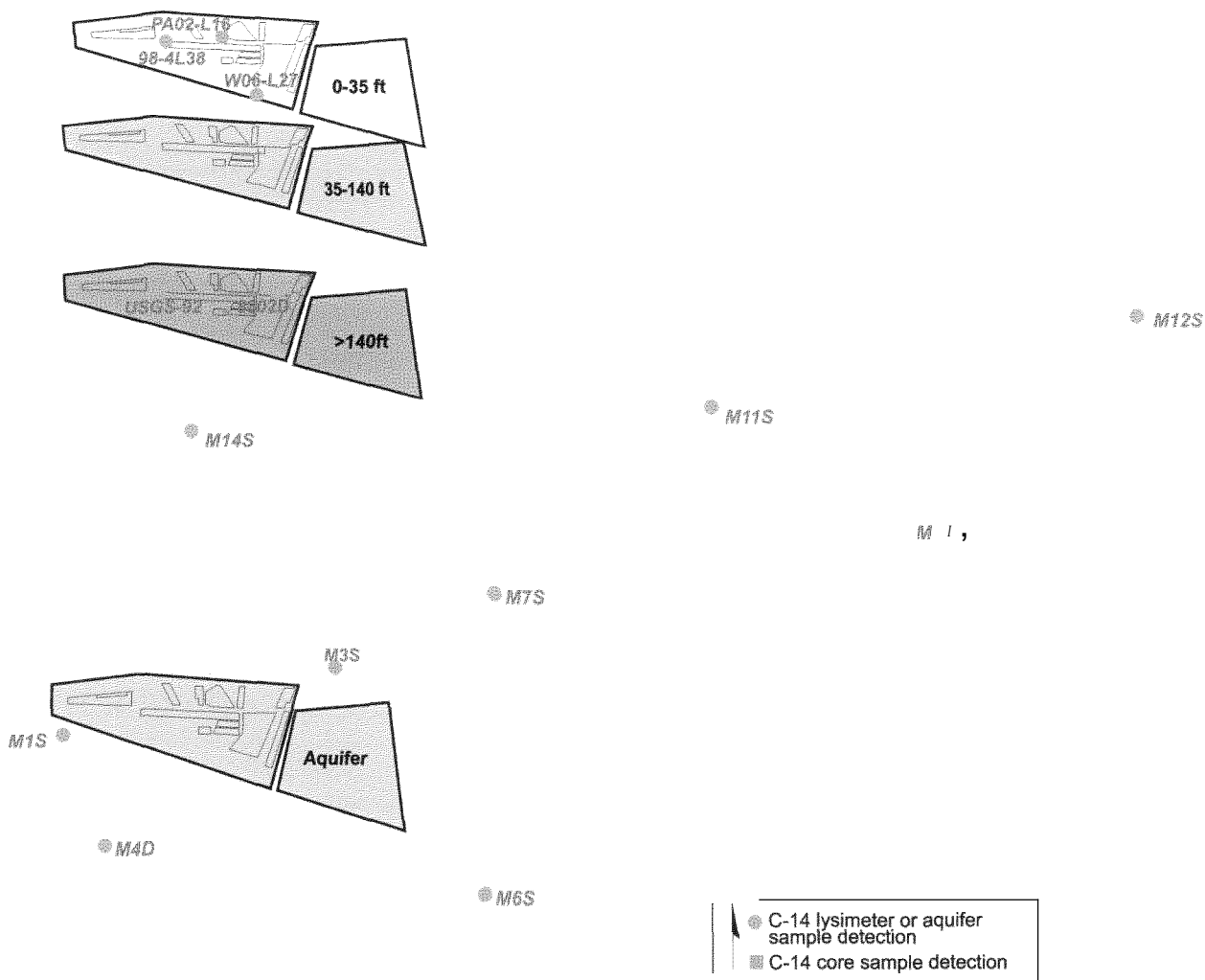


Figure 4-20. Locations of wells and lysimeters with detected concentrations of carbon-14.

4.6.5 Chlorine-36

Chlorine-36 is a radioisotope that is generated by nuclear reactor operations and weapons testing. It also is produced in extremely low concentrations in the environment by cosmic-ray interactions with argon. It decays by the emission of beta particles, has a 30,100-year half-life, and was identified in the IRA as a COPC, primarily for the groundwater ingestion exposure pathways (Becker et al. 1998). The comparison concentrations for Cl-36 are shown in Table 4-29.

Table 4-29. Comparison concentrations for chlorine-36 in groundwater and soils.

Surface Soil Background Concentration (pCi/g)	Risk-Based Soil Concentration ^a (pCi/g)	Aquifer Background Concentration	Maximum Contaminant Level (pCi/L)	Risk-Based Aquifer Concentration ^a (pCi/L)
Not established	10.4	Not established	700	144

a. Calculated risk-based concentration equivalent to an increased cancer risk of 1E-05.

Approximately 1.11 Ci of Cl-36 were disposed of in the SDA. Table 4-30 identifies the waste streams containing the majority of Cl-36 activity. Gamma spectral logging data provide no information about Cl-36.

Table 4-30. Waste streams containing chlorine-36.

Waste Stream Code or Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
Test Reactor Area	Beryllium blocks	6.62E-01	59.9
OFF-UBM-1H	Ore processing waste	3.43E-01	31.0
NRF-618-8R	Structural components removed from Navy nuclear fuel modules (e.g., end boxes) 1989 to 1993	1.01E-01	9.1
Total Disposals		1.11E+00	100

No analytical data are available for Cl-36. In the evaluation of vadose zone core samples collected during well drilling from 1971 to 2000, Cl-36 was not analyzed. Historically, Cl-36 has not been included on the radionuclide target list provided to the analytical laboratories subcontracted to the INEEL. In September and December 2001, Cl-36 analysis was performed on INEEL aquifer samples. Of the 15 wells sampled, none had detectable concentrations of Cl-36.

4.6.5.1 Summary of Chlorine-36. Analytical data to evaluate the nature and extent of Cl-36 are not available because Cl-36 has not been a target analyte for environmental monitoring.

4.6.6 Cesium-137

Cesium-137 is a radioisotope that is produced from nuclear reactor operations and weapons testing. It decays by the emission of beta particles and gamma rays, has a 30-year half-life, and is ubiquitous in the environment at low levels as a consequence of atmospheric bomb testing. The IRA identified Cs-137 as a COPC primarily for the external exposure pathways (Becker et al. 1998).

Cesium-137-bearing waste in the SDA and the available Cs-137 monitoring data for all media are summarized below. The sampling data in this section are evaluated against the comparison concentrations in Table 4-31.

Table 4-31. Comparison concentrations for cesium-137 in groundwater and soil.

Surface Soil Background Concentration ^a (pCi/g)	Risk-Based Soil Concentration ^b (pCi/g)	Aquifer Background Concentration (pCi/L) ^c	Maximum Contaminant Level (pCi/L)	Risk-Based Aquifer Concentration ^b (pCi/L)
0.82	183	0	200	15.7

a. Upper 95% tolerance limit with 95% confidence for composited surface soil (Rood, Harris, and White 1996).

b. Calculated risk-based concentration equivalent to an increased cancer risk of 1E-05.

c. Knobel, Orr, and Cecil (1992).

4.6.6.1 Waste Zone. Approximately 6.17E+05 Ci of Cs-137 were disposed of in the SDA. Table 4-32 identifies the waste streams containing the majority of Cs-137 activity.

Table 4-32. Waste streams containing cesium-137.

Waste Stream Code or Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
Idaho National Engineering and Environmental Laboratory (INEEL)	INEEL reactor operations	1.32E+05	21.4
TRA-603-15H	Metal	1.04E+05	16.9
ANL-765-2H	Subassembly hardware	8.94E+04	14.5
TRA-642-6H	Scrap metal	6.02E+04	9.8
Miscellaneous	Miscellaneous minor streams	4.75E+04	7.7
TRA-603-1H	Resins	4.86E+04	7.9
ANL-785-1H	Subassembly hardware	4.23E+04	6.9
TRA-603-4H	Core and loop components	2.64E+04	4.3
OFF-ATI-1H	Fuel	2.56E+04	4.2
TRA-603-9H	Fuel	2.20E+04	3.5
ANL-765-1H	Dry active waste	1.10E+04	1.8
CPP-633-1H	High-efficiency particulate air filters	7.76E+03	1.3
Total Disposals		6.17E+05	100

The gamma spectral logging tool detected Cs-137 based on the 662 keV gamma rays. Of the 135 probeholes logged using this tool, 43 (32%) showed the presence of Cs-137 above the noise level. Of the 4,863 total measurements collected from all probes at all depths, 359 (7%) showed the presence of Cs-137 above the noise level. The Cs-137 detection limit was approximately 0.3 pCi/g. The maximum and average observed Cs-137 levels were 141 and 5.3 pCi/g, respectively. The detection limit, maximum concentration, and average concentration are based on the assumption that Cs-137 is uniformly distributed in the vicinity of the measurement points.

4.6.6.2 Surface. A total of 186 soil samples collected between 1994 and 2000 from in and around the RWMC were analyzed for Cs-137, yielding 80 positive detections. The positive results ranged from 0.07 ± 0.02 to 1.19 ± 0.10 pCi/g (INEEL 2001).

A total of 124 vegetation samples collected between 1990 and 2000 from the RWMC were analyzed for Cs-137 resulting in one positive detection of 0.22 ± 0.06 pCi/g (LMITCO 1998).

A total of 210 surface run-off water samples collected from the RWMC between 1991 and 2000 were evaluated for Cs-137, yielding 13 positive detections. The positive results ranged from 0.7 ± 0.2 pCi/L (EG&G 1994) to 37 ± 3 pCi/L (LMITCO 1997).

4.6.6.3 Vadose Zone. The distributions of Cs-137 in vadose zone core, soil moisture, and perched water in the various depth intervals are discussed below.

4.6.6.3.1 Vadose Zone Core Samples—A total of 290 vadose zone core samples from well drilling were analyzed for Cs-137 between 1971 and 2000, resulting in 13 positive detections (see Table 4-33). None of the positive detections were greater than the $1\text{E-}05$ RBC for soil or above the surface soil background concentration for the INEEL (Rood, Harris, and White 1996). Seven of the 13 detections are associated with data from the early 1970s, which are known to be questionable (Barraclough et al. 1976; DOE-ID 1983). The detection rates for the various depth intervals are shown in Table 4-34.

Table 4-33. Positive detections of cesium-137 from vadose zone core samples.

Borehole Identification	Sample Depth (ft)	Concentration \pm 1 σ (pCi/g)	Date
D10	0	0.37 ± 0.04	1994
3E	3 to 5.5	0.09 ± 0.02	1994
6V	2 to 10	0.106 ± 0.019	1994
USGS-93	98.0 to 101.0	0.10 ± 0.02 "	1972
78-3	226.9	0.07 ± 0.02	1978
79-1	114.8 to 121.2	0.08 ± 0.02	1979
	121.6 to 223.4	0.08 ± 0.02	1979
USGS-89	241.6 to 243.2	0.040 ± 0.010 "	1971
USGS-92	223.0 to 225.5	0.13 ± 0.03 "	1972
USGS-94	262.3 to 264.6	0.18 ± 0.03^a	1972
USGS-95	112.0 to 113.3	0.220 ± 0.010^a	1972
	226.8 to 229.3	0.23 ± 0.03 "	1972
USGS-96	122.8 to 124.8	0.55 ± 0.04^a	1972

a. The 1971 to 1972 data must be used with discretion. They are questionable because of cross-contamination concerns (see Section 4.5.5).

Table 4-34. Summary of Cs-137 occurrences in vadose zone core samples.

Depth Interval (ft)	Number of Cs-137 Detections/Number of Samples (%)	Concentration Range (pCi/g)	Cores with Detections
0 to 35	3/33 (9.1)	0.09 to 0.37	3E, 6V, D10
35 to 140	5/120 (4.2)	0.08 to 0.55	93, 95, 96, 79-1
140 to 250	4/129 (3.1)	0.040 to 0.23	78-3, 89, 92, 95
Greater than 250	1/8 (12.5)	0.18	94

Because Cs-137 is known to be present in surface soils from nuclear fallout at concentrations approximating 0.82 pCi/g (Rood, Harris, and White 1996), the potential exists for introducing surface contamination into samples during coring and collection. Cesium-137 was detected in the background Well 79-1.

4.6.6.3.2 Lysimeter Samples at Depths from 0 to 35 ft—A total of 101 shallow lysimeter samples were analyzed for Cs-137 between 1997, when Cs-137 monitoring began, and May 2001, with two positive detections (see Table 4-35). Sample volumes were not sufficient to reanalyze and confirm the positive detections. The high Cs-137 result obtained in September 2000 from Well 98-1L35 (SDA-01) of $1,760 \pm 136$ pCi/L was a single event and subsequent samples collected from this lysimeter through May 2001 have shown no positive Cs-137 detections. The detections of Cs-137 in the shallow lysimeters are depicted in Figure 4-21.

Table 4-35. Positive detections of cesium-137 in shallow lysimeters.

Lysimeter	Depth (ft)	Number of Analyses and Sampling Events	Concentration \pm 1a (pCi/L)	Confirmation Flag	Date
PA01-L15	14.3	11 analyses 8 events	324 ± 24	A	April 1996
98-1L35 (SDA01)	16.5	6 analyses 6 events	1760 ± 136	A	September 2000

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

Note: Values in **red bold** indicate that the concentration exceeds the M U of 200 pCi/L. The M U does not apply to lysimeter samples, but is used here as a basis of comparison.

4.6.6.3.3 Lysimeter Samples at Depths from 35 to 140 ft—A total of 38 samples from 12 lysimeters were analyzed for Cs-137 between 1997, when Cs-137 monitoring began, and May 2001, with no positive detections. Only the Lysimeters D06-DL02, TW1-DL04, and D15-DL06 yielded enough sample to run analyses for Cs-137. The other lysimeters did not yield enough volume of water to perform the analysis.

4.6.6.3.4 Perched Water Samples at Depths Greater than 140 ft—A total of 53 perched water samples and five filtered sediment samples were analyzed for Cs-137 by the USGS and INEL between 1972 and September 2000. No positive detections of Cs-137 were identified in samples collected from perched water Wells USGS-92 and 8802D. No data are available for the deep lysimeter samples because the volume of water collected was insufficient to perform the analyses.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01- L15	PA02- L16	PA03- L33	W06- L27	W08- L13	W08- L14	W23- L08	W23- L09	W25- L28
1996	1												
	2				324								
	3												
	4												
1997	1												
	2												
	3												
	4												
1998	1												
	2												
	3												
	4												
1999	1												
	2												
	3												
	4												
2000	1												
	2												
	3	1760											
	4												
2001	1												
	2												
	3												
	4												
Key		Analysis was performed for Cs-137, but none was detected.											
		Cs-137 was detected (pCi/L).											
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.											

Figure 4-21. Occurrences of cesium-137 detections in the shallow lysimeters.

4.6.6.4 Aquifer. A total of 197 samples from 16 aquifer wells around the RWMC were analyzed for Cs-137 between 1996 and April 2001, with three positive detections of Cs-137 (see Table 4-36). Only the sample from Well M4D was reanalyzed, and the detection was not confirmed. Subsequent samples collected from these wells through April 2001 have not shown positive detections. Figure 4-22 shows the occurrence of positive detections and nondetections of Cs-137 in INEEL and USGS wells.

Table 4-36. Positive detections of cesium-137 in aquifer well samples collected between the years 1996 and 2001.

Aquifer Well	Concentration \pm 1a (pCi/L)	Confirmation Flag ^a	Date
M4D	20 \pm 6	B	April 1996
M12S	7.8 \pm 1.1	A	September 2000
M13S	7.6 \pm 1.2	A	September 2000

a. Confirmation flag:

A = No second sample collected, no reanalysis performed

B = Reanalysis performed, no confirmation

Note: Values in **red bold** indicate that the concentration exceeds the 1E-05 risk-based concentration of 15.7 pCi/L.

In addition to the 16 RWMC monitoring aquifer wells managed and routinely sampled by INEEL, the USGS manages, controls, and routinely samples eight other wells in the vicinity of the RWMC. A total of 496 USGS aquifer well samples in the vicinity of the RWMC were analyzed for Cs-137 between 1972 and October 2000, with 10 detections (see Table 4-37). The occurrence of detection and nondetections is shown in Figure 4-23.

Table 4-37. Positive detections of cesium-137 in aquifer well samples collected by the U.S. Geological Survey between 1972 and 2000.

Aquifer Well	Concentration $\pm 1\sigma$ (pCi/L)	Date
USGS-87	90 \pm 20 ^a	October 1973
	1020 \pm 30	January 1995
USGS-88	24 \pm 5 ^a	November 1972
	30 \pm 9	September 1987
USGS-89	90 \pm 10 ^a	September 1972
	27 \pm 6 ^a	October 1972
	24 \pm 7	October 1976
	25 \pm 6	September 1987
USGS-90	30 \pm 6 ^a	February 1972
	90 \pm 10 ^a	October 1972

a. The data from 1972 to 1974 must be used with discretion. They are questionable because of cross-contamination concerns (see Section 4.5.5).

Note: Values in red bold indicate that the concentration exceeds the 1E-05 aquifer risk-based concentration of 15.7 pCi/L.

Year	Quarter	USGS-87	USGS-88	USGS-89	USGS-90	RWMC Prod	USGS-117	USGS-119	USGS-120
1972	1				30				
	2								
	3			90					
	4		24	27	90				
1973	1								
	2								
	3								
	4	90							
1974	1								
	2								
	3								
	4								
1975	1								
	2								
	3								
	4								
1976	1								
	2								
	3								
	4			24					
1977	1								
	2								
	3								
	4								
1978	1								
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1979	1								
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1988	1								
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1989	1								
	2								
	3								
	4								
1990	1								
	2								
	3								
	4								
1991	1								
	2								
	3								
	4								
Key		Analysis was performed for Cs-137, but none was detected.							
		Cs-137 was detected (pCi/L).							
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.							

Figure 4-23. Occurrences of cesium-137 detections in the aquifer monitoring wells from 1972 through 1991.

Six of the **10** detections in the **USGS** wells occurred between **1972** and **1974**, shortly after the wells were drilled and installed. The **1972** to **1974** detections are suspect because of cross-contamination problems associated with early well drilling and well construction techniques, and the types of sampling methodology employed at that time (Barraclough, et al. **1976**, Section **4.4**). After **1974**, only four **USGS** samples have contained detectable amounts of **Cs-137**. The high **Cs-137** result obtained from Well **USGS-87** in January **1995** (**1,020 ± 30 pCi/L**) was a single event and subsequent samples collected from this well have not shown positive detections. Furthermore, Well **USGS-087** is hydrologically upgradient from the SDA.

4.6.6.5 Summary of Cesium-137. In the **IRA** (Becker et al. **1998**), **Cs-137** was identified as a **COPC** for external exposure. Approximately **6.17E+05 Ci** of **Cs-137** were disposed of in the SDA. Spectral gamma logging data indicate that **32%** of the probeholes contained detectable **Cs-137**, while **Cs-137** was detected in about **5%** of the vadose zone core samples (see Table **4-38**) at background levels.

Two high concentrations were detected in lysimeter samples at an approximate depth of **15 ft** but the samples were not in close proximity and subsequent detections from the same lysimeters did not occur. Overall, **Cs-137** was detectable in only **2%** of the shallow (i.e., **0** to **35 ft**) lysimeters and none of the intermediate depth (i.e., **35** to **140 ft**) to deep vadose zone samples (depths greater than **140 ft**) (see Table **4-38**). Detectable levels of **Cs-137** were present in approximately **2%** of the aquifer well samples, but detections in the aquifer were sporadic.

The distribution of **Cs-137** in the sampled media is shown in Figure **4-24**. In general, **Cs-137** occurs sporadically throughout the vadose zone and aquifer in and around the SDA, but there are no evident spatial or temporal trends. Vadose zone samples suggest that **Cs-137** has not leached deeper than **35 ft**. No obvious trends are associated with **Cs-137**; however, occasionally **Cs-137** has been detected in samples at relatively high levels. There does not seem to be any pattern to its occurrence.

Table **4-38**. Detection rates of cesium-137 in the sampled media.

Media	Detection Rate (%)	Range of Detected Concentrations	Total Number of Detections Greater than the Risk-Based Concentration	Wells with Concentrations Greater Than the Maximum Contaminant Level
Source	Probeholes: 32 Measurements: 7	0.3 to 141 pCi/g	0	None
Surface soil	43.0	0.07 to 1.19 pCi/g	0	None
Run-off water	6.2	0.7 to 37 pCi/L	0	None
Vadose zone 0 to 35 ft:				
Cores	9.1	0.09 to 0.37 pCi/g	0	None
Soil moisture	2.0	324 to 1760 pCi/L	2	PA01, 98-1
Vadose zone 35 to 140 ft:				
Cores	4.2	0.08 to 0.55 pCi/g	0	None
Soil moisture	0	Not applicable (NA)	0	None
Vadose zone >140 ft:				
Cores	3.6	0.04 to 0.23 pCi/g	0	None
Soil moisture	0	NA	0	None

Table 4-34. (continued).

Media	Detection Rate (%)	Range of Detected Concentrations	Total Number of Detections Greater than the Risk-Based Concentration	Wells with Concentrations Greater Than the Maximum Contaminant Level
Aquifer-Idaho National Engineering and Environmental Laboratory	1.5	7.6 to 20 pCi/L	1	M4D
Aquifer-U.S. Geological Survey	2.0	24 to 1020 pCi/L	10	USGS-87, -88, -89, -90

a. For surface soil and cores, the 1E-05 risk-based concentration (RBC) for soil is 183 pCi/g. For soil moisture and aquifer, the values are compared to the 1E-05 aquifer RBC, which is 15.7 pCi/L. The 1E-05 aquifer RBC does not apply to soil moisture, but is used here only as a basis of comparison.

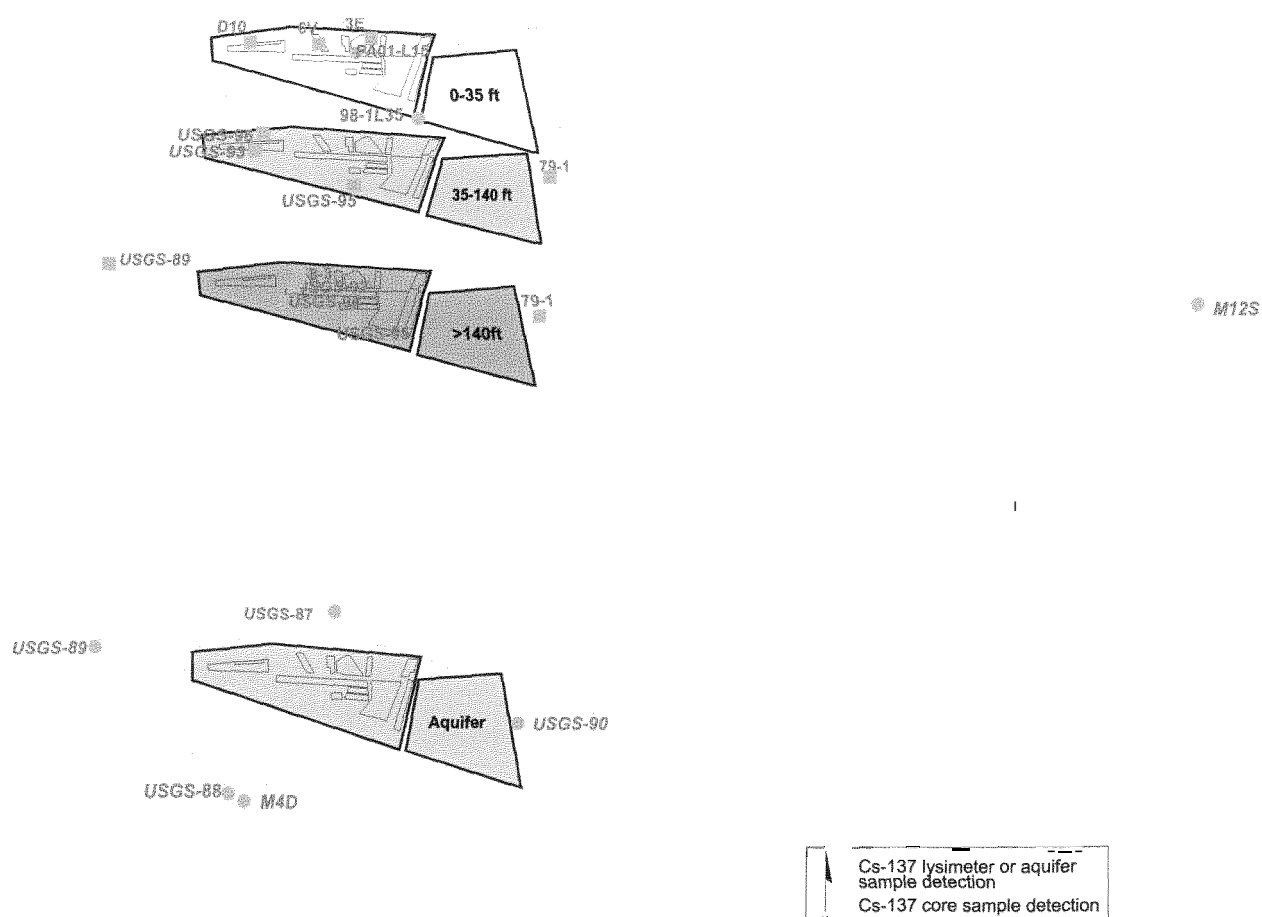


Figure 4-24. Distribution of cesium-137 in the various sampled depths in the vadose zone and aquifer.

4.6.7 Tritium

Tritium (H-3) is a radioisotope of hydrogen that is produced from nuclear reactor operations and weapons manufacturing and testing. It also is produced in the environment by interactions of cosmic rays with gases in the atmosphere. It decays by the emission of beta particles with a half-life of 12.3 years.

Though tritium was not identified in the IRA as a COPC, its nature and extent is described here because of its potential use as a vapor-phase model calibration target for future modeling planned for OU 7-08, the OCVZ Project. In addition, a significant H-3 trend has been observed in lysimeter Well W06, and elevated H-3 concentrations in lysimeter Well TW1 at 102 ft. These may be connected to a small isolated H-3 plume in the aquifer beneath the SDA. The H-3 data associated with all lysimeters may ultimately provide valuable ancillary information about contaminant migration in the vadose zone and the source of the isolated H-3 plume beneath the SDA. The H-3 background concentration range in the aquifer is 0 to 40 pCi/L (Knobel, Orr, and Cecil 1992), and the MCL is 20,000 pCi/L.

4.6.7.1 Waste Zone. Gamma spectral logging data provide no information about tritium.

4.6.7.2 Surface. No surface data are available for H-3.

4.6.7.3 Vadose Zone. Tritium has not been detected in vadose zone core samples. The distributions of H-3 in soil moisture and perched water in the various depth intervals are discussed below.

4.6.7.3.1 Lysimeter Samples at Depths from 0 to 35 ft—A total of 56 shallow lysimeter samples were analyzed by INEEL for H-3 between 1997 and September 2000, with 22 detections in eight lysimeters. The positive results varied from a minimum of 129 ± 34 pCi/L (Well W08-L14) to a maximum of $9,100 \pm 1,180$ pCi/L (Well W06-L27). All of the detected concentrations are less than the aquifer MCL, and all except some samples from Well W06-L27 (11.8-ft deep) are less than 2,000 pCi/L.

Most of the detections occurred sporadically and infrequently, with the exception of samples collected from lysimeter Wells W06 and PA02. Lysimeter Well W06 is located in the southeast corner of the SDA, and Well PA02 is near Pad A. The H-3 in lysimeter Well W06-L27 is most likely from the TRA beryllium blocks that are disposed of nearby. Well PA02-L16, which is located in the southern end of Pad A at an 8.5-ft depth, also has frequent positive detections that appear to be trending upwards; however, when combined with the nondetects, the trend is obscured. Subsequent samples collected from the lysimeters, other than lysimeter Wells W06-L27 and PA02-L16, have not shown detectable H-3.

4.6.7.3.2 Lysimeter Samples at Depths of 35 to 140 ft—A total of eight lysimeter samples from the three wells were analyzed for H-3 between 1997 and November 1998, with three positive detections, all in TW1-DL04. Results ranged from 1,680 to 2,950 pCi/L, and all detections were in 1998. Samples were only obtained from Lysimeters D06-DL02, TW1-DL04, and D15-DL06. The other lysimeters did not yield sufficient water volume to perform analyses.

4.6.7.3.3 Perched Water Samples from Depths Greater than 140 ft—A total of 45 perched water samples and eight filtered sediment samples were analyzed for H-3 by the USGS and INEEL between 1972 and November 1999. Eight positive detections were measured, which ranged from 169 to 1,570 pCi/L. All detected concentrations were from samples taken from Well USGS-92. None of the results exceed the MCL of 20,000 pCi/L.

Subsequent samples collected from Well USGS-92 in the two later sampling events (March and November 1999) did not contain detectable H-3. The deep lysimeter well samples were not analyzed for H-3 because the volume of water collected was insufficient to perform the analysis.

4.6.7.4 Aquifer. A total of 284 RWMC aquifer well samples were analyzed by INEEL for **H-3** between 1992 and April 2001, with 107 detections. The positive results varied from 398 ± 87 pCi/L to $2,600 \pm 400$ pCi/L (107 measurements), with the majority of values between 1,100 to 1,800 pCi/L. Six of the INEEL wells in the vicinity of the RWMC contain H-3 concentrations above SRPA background levels but much below the MCL of 20,000 pCi/L. Those wells are **M3S, M7S, M12S, M14S, M16S, and M17S** and have been monitored since 1992. Wells **M3S** and **M7S** are close to the **SDA** but the rest of the wells are 805 m (0.5 **mi**) or more upgradient. Tritium concentrations in Wells **M3S** and **M7S** are trending slightly down over time, which may be related to the decay of H-3 over time and dispersion in the aquifer.

In addition to the 16 RWMC monitoring wells routinely sampled by INEEL, the USGS manages, controls, and routinely samples eight other wells in the vicinity of the RWMC. These eight wells have been monitored by the USGS for H-3 since 1972. A total of 700 USGS aquifer well samples in the vicinity of the RWMC were analyzed for H-3 between 1972 and October 2000, with 236 detections. The most frequent detections come from the RWMC Production Well, where 90 out of 93 analyses contained concentrations of detectable H-3; Well USGS-87, with 62 detections out of 118 samples; and Well USGS-90, yielding 82 detections out of 111 samples. The H-3 concentrations are about an order of magnitude below the MCL, but above background. The concentration ranges measured by the USGS correspond with that of the INEEL well data.

The Site-wide environmental monitoring program has been sampling the RWMC Production Well since 1995 to comply with State of Idaho drinking water monitoring requirements. A total of 23 RWMC Production Well samples were analyzed for H-3 between 1995 and May 2001. The well routinely shows H-3 levels above background but significantly below the MCL of 20,000 pCi/L. The positive results varied from $1,090 \pm 135$ to $2,800 \pm 225$ pCi/L, with the majority of positive values between 1,200 and 1,800 pCi/L. These concentration ranges correspond with that of the USGS and INEEL well data.

An H-3 plume is known to extend many miles south of the TRA and INTEC facilities, though the plume appears to have little or no impact on the aquifer directly beneath the RWMC. A small isolated H-3 plume beneath the RWMC extends to the northwest and does not appear to have any association with the current TRA and **INTEC** H-3 plumes, as evidenced by the lack of H-3 detections from Wells **M11S** and **M13S**.

4.6.7.4.1 Special Tritium Studies in Area of Activated Beryllium—The following excerpts and figures are from monitoring studies^b conducted by Paul **D. Ritter** near the activated beryllium buried at the RWMC.

Six activated beryllium reflector blocks from the ATR were buried in the southeast corner of the **SDA** in 1993. These blocks contained a total of 293,300 Ci of tritiated hydrogen gas. The tritiated hydrogen gas is oxidized to tritiated water in the soil surrounding the beryllium. Soil moisture monitoring in the shallow vadose zone started in 1994 to characterize the migration of H-3 from the beryllium blocks.

b. P. D. Ritter Interdepartmental Memorandum to R. R. Seitz, October 2, 2001. "Transmittal of FY-2001 Summary Report of Results of Monitoring Near Activated Beryllium at SVR-20," PDR-07-01, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

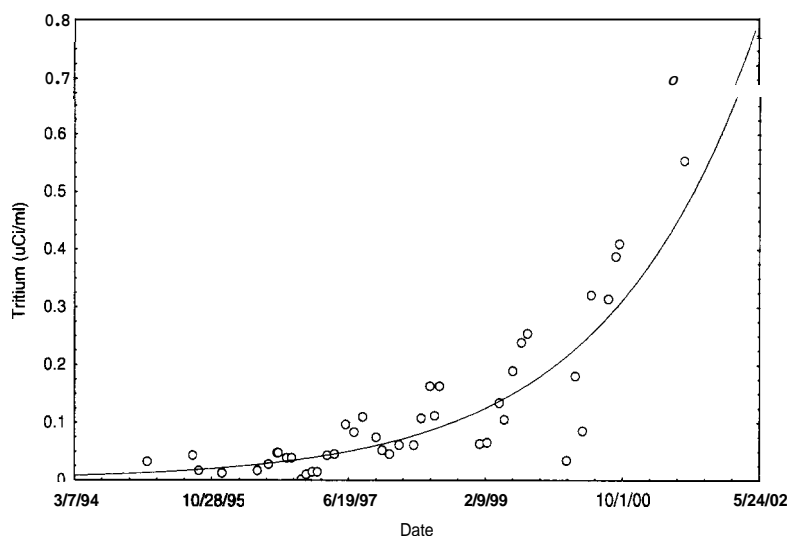


Figure 4-25. Tritium concentration in soil moisture at 20.3-ft depth.

The soil moisture samples were collected approximately 2 to 3 ft from the buried beryllium at depths of 8.9, 14.7, and 20.3 ft. The H-3 concentrations in soil moisture near the beryllium blocks showed significant trends that reached maximum concentrations of 3.4 µCi/ml (3.4E+09 pCi/L) at 8.9 ft, 0.28 µCi/ml (2.8E+08 pCi/L) at 14.7 ft, and 0.70 µCi/ml (7.0E+08 pCi/L) at 20.3 ft (see Figure 4-25 for 20.3-ft depth example).

The concentration of H-3 observed in soil moisture over long periods of time has a nonlinear trend. This trend cannot continue indefinitely, but there is no indication that the concentrations will peak or plateau over the next few years. The H-3 trend associated with lysimeter Well W06 (i.e., 197 ft) west of borehole SVR-20) suggests a large area near the buried beryllium has been impacted by the radial distribution (migration) of H-3 from the beryllium blocks.

Air samples also are collected a few feet above ground over the buried beryllium blocks (near borehole SVR-20). Environmental monitoring samples are routinely collected throughout each year. Additional intensive sampling is conducted by Waste Management Projects during summer and early fall of each year. The H-3 concentrations measured in ambient air vary considerably during the year, with peak concentrations occurring during the late summer months. Tritium concentrations in ambient air have reached peak concentrations around 1E+05 to 1E+06 pCi/m³. The estimated amounts of H-3 released to the atmosphere each year vary from less than 1 Ci to more than 100 Ci.

4.6.7.5 Summary of Tritium. Tritium is regularly detected above background in several lysimeters and wells near the SDA (see Table 4-39). The past 4 years of H-3 data from the shallow lysimeters (i.e., 56 analyses) do not contain sufficient evidence to conclude that H-3 in the vadose zone is contributing to the isolated H-3 plume in the aquifer beneath the SDA. Wells upgradient from the SDA contain detectable H-3 and it is possible that these detections are associated with a plume from upgradient rather than from the SDA. More data are needed to define whether the aquifer occurrences are attributable to SDA, TRA, or INTEC.